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OUTLINE ANALYSIS FOR MINING SECTOR

SUDANO-SAHELIAN REGION

Special Sahilian Office

74-03167

MINERAL RESOURCES PROGRAMME
IN THE SAHELIAN REGION

I. The Problem

1. The inherent difficulties of any exploration (not alone exploitation) in arid or semi-desert areas, namely the scarcity of water, labour, and access roads, are compounded in the case of mineral exploration by certain limitations in the applicability of geochemical and geophysical methods, that is precisely those most suitable for the exploration of vast areas.

2. Mineral exploration is a very long-term undertaking, which external assistance can only help start. There are no (or no longer) jackpots; there is no predictable relationship between the amount of time and money spent and the results to be expected, if any. On the other hand, successful mineral exploration followed by mining development can provide a framework for a sectorial development of hitherto desert regions, as was the case in the Atacama desert in Chile, and, in the USSR, in Kazakhstan.

3. Those who decide, before deciding on an aid in mineral exploration, must be aware (or made aware) that they must be prepared to support a long-term effort (with incidental outside expertise only), in the form of permanent institutions and recurrent budgetary provisions (the latter in the form of overhead rather than new investment) and training programmes. Some disillusions will arise if no financial advantages are granted for work under hardship conditions.

4. [illegible] with metallic and certain industrial minerals. Coal and other solid fuels will be dealt with in the report on [illegible]

4. The rational planning of mineral exploration, whether local or regional, rests on the knowledge of all work done and all information gathered prior to inception. The United Nations does not possess that information in any comprehensive manner, nor do the recipient governments, as far as their countries are concerned. There are difficulties in obtaining it from certain bilateral donors. This is not to say that any further fieldwork has to await the availability of such full knowledge (proposals for such fieldwork are made in Annex III), but systematic data gathering is urgent.

5. The awareness of all the above by governments is necessary if they are to be able to appraise realistically the prospects of mineral exploration before they include them in their development plans or programmes, when financial and human resources are limited and anyhow, the countries have only a limited absorption capacity for development assistance.

6. An exception must be made in favour of locally available "common" materials suitable for local or regional industries. For their lack of glamour, they are too often disregarded, to the point of leading to substantial imports (see Annex I).

II. Significance of the mineral sector to the economy and its relationship to other economic sectors

1. Granted that large-scale, long-term development in the Sahel would best be based on the discovery of exploitable minerals for export, mostly metallics, it remains true that the probability for the mineral sector to become economically significant in the region is uncertain, except in regard of those "common" non-metallic minerals whose production could have an immediate bearing on local or regional needs. There are road-building and road stabilization materials, building construction materials, limestone, clays for pottery, bricks, tiles and pipes, marble, salt; perhaps also small metallic deposits that may be suitable for local processing by simple means. All these would lend themselves to the early development of local industries. Their assessment deserves high priority; aside from reducing imports, small industries are alternatives to complete reliance on animal husbandry and agriculture, and to the extent that they would reduce the demand on scarce water supplies and minimize the rate of encroachment of the desert due to the over-utilization of land.

2. Aside from this category, the significance of any mineral discovery will be affected by the long-term behaviour of the world market. Furthermore, any mineral occurrence, however attractive, will need confirmation by more refined exploration work and related economic studies, followed at the proper time by contract negotiations. All this may take years: in other words, market prospects aside, the future economic potential of any discovery will always be difficult to assess. Mineral rights granted to private parties

are by themselves meaningless in this respect, unless they are laid down in exploration and exploitation contracts where the mutual obligations are unequivocally spelled out, and the government is administratively equipped to enforce them.

Contribution of Mining Sector to Gross Domestic Product in the Sahelian Countries at Current Factor Cost, Converted at Current Year-to-Year Exchange Rates

(US $ Million)

Year	MALI		NIGER		SENEGAL		UPPER VOLTA		CHAD		MAURITANIA	
	Total GDP	Mining	Total GDP	Mining	Total GDP	Mining	Total GDP	Mining	Total GDP	Mining	Total GDP	Mining
1960	249.8		193.2		507.0	1.5	172.1		169.9		76.6	2.3[a]
1961	294.3		208.6		528.3	1.5	182.3		181.0	0.5	90.0	2.3[a]
1962	264.4		232.9		557.8	1.6	193.5		192.4	0.5	93.4	2.3[a]
1963	277.9		254.0		615.6	1.7	201.4		197.9	0.5	103.5	12.4[a]
1964	313.9	0.1	252.2		662.1	1.6	206.6		207.0		128.3	28.0
1965	352.6		283.6		677.0	1.6	205.8	0.9	219.4		142.9	36.0[a]
1966	390.9		298.4		699.6	2.3[a]	216.3	0.8	217.1		154.1	43.3[a]
1967	425.3		297.0		682.6	2.3[a]	228.4		218.3		162.0	45.0[a]
1968	453.4		274.5		727.4	2.3[a]	245.3		229.5		173.3	46.8[a]
1969	464.7		277.5		685.2	2.2[a]	258.2		233.4		173.2	50.6[a]

[a] Estimate of Economic Commission for Africa

Source: Economic Commission for Africa, Survey of Economic Conditions in Africa, 1970, Part II, United Nations, New York 1971.

III. Achievements in the past

1. The incomplete knowledge of the UN in respect of work done by others has been stressed in Section I.

2. Mineral projects (non-UN) having culminated in commercial-size production are few: iron and copper ore in Mauritania, phosphate ore in Senegal, uranium ore in Niger.

3. The specific achievements of UN-assisted projects are subject of Annex II. Their common characteristic is that however well planned and executed and however great the interest and support of the governments, none of these projects so far has led to actual investment and production. While in particular the Tambao manganese deposit in Upper Volta seemed originally very attractive, there is at present no known prospect of its early development.

C. Training

1. Training at the intermediate level (assistant geologists, drillers, mechanics, chemists) seems to be adequately ensured by in-service training in the course of field projects.

2. At the academic level (geologists, geochemists, geophysicists), a regional institution seems questionable, even if the programme should be conducted jointly with that for water resources development. Indeed the teaching staff would be heavy in regard of the real training needs if over-training is to be avoided. No specific training projects are therefore proposed.

V. Potential projects

A. Short-term actions

1. Exploration of metallic and non-metallic minerals

A comprehensive and costed programme, including non-metallics, is the subject of Annex III.

Road stabilization materials are the subject of a separate Annex IV.

B. Long-term actions

The actions described below are preparatory to long-term and rational planning of mineral development.

1. Complementary aerial photography

2. Complementary photogeological interpretation

The costing of these two operations must await information requested from French sources.

3. Fact-finding mission (Data collecting)

This would be a mission of two senior economic geologists, at least one of them versed in the geology and economics of local raw materials. They would collect and complete all information available on minerals in the Sahelian countries and their exploration, including to the extent possible information so far not available from certain bilateral programmes. Their consultations would take place in Paris (Bureau de Recherches géologiques et minières or BRGM, and Institut Géographique National).

London (Institute of Geological Sciences), Brussels (European Development Fund) and Washington (US Geological Survey and Bureau of Mines), and others as requested, as well as in each of the Sahelian countries. Private mining companies are also expected to cooperate, and at least one of them, Charter Consolidated, in London, has expressed its willingness to do so. The information sought would concern geology and mineral occurrences, surveys carried out and their results, with due regard to raw materials for local processing or consumption.

The mission would take not less than 6 months, at an estimated cost of $50,000.

The possibility should also be explored of contracting, for example with the BRGM, the establishment at UN Headquarters of a documentation center based on the large amount of material which that organization has already collected and indexed, and is still collecting.

Imports of non-metallic minerals in the Sahelian countries - 1968-1969

(Metric tons)

Countries		Cement	Salt	Clay non-refractory and clay products	Stone, sand and gravel	Gypsum	Fertilizers manufactured	Sulphur	Lime
Mali	1968-	26,008	12,535	-	40	-	3,260	-	-
	1969-	22,600	17,510	-	233	-	N.A.	-	-
Niger	1968-	503	-	228	-	-	178	-	-
	1969-	N.A.	-	167	-	-	16*	-	-
Senegal	1968-	2,629	18,315	-	682	-	31,339	-	-
	1969-	2,707	45,362	-	98	83	51,689	65	-
Upper Volta	1968-	2,650	-	234	-	-	-	-	-
	1969-	6,136	-	196	-	-	-	-	-
Chad	1968-	20,319	3,068	165	198	-	1,951	-	135
	1969-	12,703	3,178	187	9	-	438	-	176
Mauritania	1968-	5,634	5,275	201	-	-	3,131	-	-
	1969-	3,285	4,800	523	-	-	2,841	-	-

* Data on nitrogenous fertilizer not available for 1969.

Source: United States Department of the Interior, Minerals Yearbook 1970, Vol. III.

ANNEX II

Results of United Nations projects executed in the Sahelian zone

This annex briefly summarizes the main results obtained by United Nations projects in the Sahelian zone. The results are followed by recommendations, if any.

CHAD

United Nations Project CHD/72/002 (1973-1975): Mineral Exploration and Strengthening of the Geological Survey

UNDP Contribution: $630,750

Objectives:

Strengthening of the Geological Survey;

Construction of living quarters and laboratory;

Equipment and activation of the laboratory;

Geological reconnaissance in several parts of the country: proposed are mainly the Sahelian zones, which, however, due to unrest, will not be accessible.

Possible targets:

Based mostly on geological assumption and analogy as well as already localized indications the targets may be grouped as follows:

TIBESTI	Sn, Nb, Ta, Cu
MAYO-KEBBI	Au, Pt, Cu, Ni, Co, Cr, bauxite, limestone
ENNEDI	U, Zn, Cu, Pb (stratiform)
CHAD BASSIN	Diatomite, salines, phosphates
OUADDAI	Rare earths
GUERRA	Kaolin

Actually the project is located in the Southwestern part of Chad. The objectives are the reconnaissance for gold, platinum, carbonatite minerals, nickel, copper, cobalt related to ultrabasic rocks and non-metallics.

MALI

Mali (1970-1972): Exploration in the West of Mali (pre-project)

October 1970 - July 1972

UNDP Contribution: $186,325

Objectives:

Pre-project aiming at the applicability of reconnaissance methods (mainly geochemistry) in an area adjacent to the Senegal river project. The area covered is 42,000 km^2.

Results:

Cu-indications associated with:

a) dolerite dykes, weak and insignificant

b) quartz lenses, " " "

c) synsedimentary baryte, undetermined importance.

Baryte stratigraphically controlled, occurring at the contact of carbonate rocks. Undetermined economic value.

Pegmatite veins sometimes several km long and several meters thick. They have been found to carry spodumen. Value undetermined. The conclusions do not warrant a United Nations project. Some prospects for exploration do exist in the Birrimian basement, South of Kayes.

MAURITANIA

Mauritania MAU-4 (1971-1973): Strengthening of the Geological Service and Mineral Exploration

September 1971 - December 1973

UNDP Contribution: $420,794

Objectives:

Establishment of a functioning geological survey, procurement of the equipment and reconnaissance of a 100,000 km^2 territory in N.E. Mauritania.

Results:

The project carried out photogeological studies and geological reconnaissance in the area of the Dorsale de Regibat. Although the geological setting seemed a priori interesting, it turned out to be less than favourable. The area is composed of an old crystalline basement deeply eroded. The results were generally negative and one copper prospect examined (Blank) does not seem to be interesting.

Conclusion:

The local UNDP Resident Representative does not favour the continuation of the United Nations Mineral Survey.

NIGER

Niger: 2 1/2 years I and II phase project

October 1967 - March 1973

UNDP Contribution: $2,928,700

Results are not encouraging. The final report is currently in preparation.

SENEGAL

The United Nations assistance in the mineral survey of Senegal began in 1963 and extended over a period of 10 years. The third phase of this survey has just been completed in 1973.

SEN-7 (Phase I 1963-1965, Phase II 1965-1969): Mineral Exploration in Eastern Senegal

Phase I

January 1963 - October 1965

UNDP Contribution: $999,500

The project was initiated on the basis of an airborne geophysical survey. In the first phase, a general reconnaissance has been carried out.

Phase II

November 1965 - August 1969

UNDP Contribution: $566,300

In the second phase, the most important mineral indications have been evaluated.

a) Molybdenum showings in the region located between Kanémésé and Falémé. The results were completely negative.

b) Iron ore deposits of Mt. Kouroudiaho and Mt. Karakaéné were studied for eventual occurrence of base metal sulphides, with negative results.

c) Gold prospecting in several river basins indicated alluvial gold reserves totalling over 10 tons with grades from 0.2 to 1.5 gr/t however under substantial sterile overburden. Investigation of primary gold occurrences gave encouraging results. Two zones of quartz veins showed values from 4 to 25 gr/t and 2 to 75 gr/t respectively.

d) Prospecting for alluvial diamonds in Eastern Senegal was negative and there seem to be very poor chances for finding economically interesting kimberlite pipes.

e) Small concentrations of chromite have been discovered in the Gabou region in a large zone of basic and ultrabasic rocks so far, however, of negligible tonnage (2,000 - 4,500 T).

f) Interesting copper mineralization has been located within the zone of basic and ultrabasic rocks of Gabou. Borehole intersections indicated Cu values 0.5-2.5% plus 4 gr/t and 5 gr/t Ag.

Phase III

January 1970 - August 1973

UNDP Contribution: $410,000

A detailed assessment of the copper bearing zone Bakel-Gabou-Alinguel has been carried out.

a) It has been established that copper mineralization appears in a geologically favourable environment (deep fractures within volcano sedimentary formations). The values from boreholes gave 0.6 to 1.5% Cu, however, the complicated tectonics seem to diminish substantially the economic value of the prospected occurrences and no further exploration is recommended.

b) Limited nickel indications have been located within the zone of Gabou and their exploration is suggested.

UPPER VOLTA

The United Nations has been engaged in mineral exploration in Upper Volta since 1965, and has executed three mineral survey projects, (UPV-4, UPV-6, UPV-16) of which the last one was completed at the end of 1973. The government of Upper Volta has already requested the second phase for the current project to be extended until the end of 1975.

Summary of results:

Project UPV-4 (1965-1968): Exploration in the South-west of Upper Volta

UNDP Contribution: $1,003,139

a) Preliminary copper ore estimation in the Diemenera zone:

9,544,000 t Cu 1.38%

23,100,000 t Cu 0.5%

Mineralization: chalcopyrite, pyrite, minor molybdenite, gold 0.1-0.2 gr/t in altered, brecciated rocks forming linear (tabular) orebodies.

b) Gold in the Diebougon region, both alluvial and in primary quartz veins, is of no economic significance.

c) Diamond prospecting remained without firm conclusions. A few small diamonds both of gem and industrial quality have been found in several rivers in the project area and further prospecting has been proposed.

Project UPV-6 (1967-1970): Exploration in the Northeast of Upper Volta
(In the regions adjacent to the projected railway.)

November 1966 - September 1970

UNDP Contribution: $1,096,100

a) Detailed exploration of the Tsabuc manganese deposit.

11.5 million t of commercial Mn oxide ore with 54-55% Mn.

The mine development would require some US $8.5 million (1970 estimate) for the production of 575,000 t ore annually.

b) Exploration of Tin Hvasan limestones.

6 million t of limestone with 46% CaO suitable for the production of Portland cement. A proposition for 100,000 t/year cement factory was estimated between US$ 9-13 million.

c) Detailed exploration of vanadium-bearing, titaniferous magnetites in the Ourai-Tin Edia region. Several tens of million tons (50) of ore of lenticular occurrence average 45-50% Fe, 9-13% TiO_2 and 0.7% V_2O_5 (vanadium pentoxide). The testing indicated that ilmenite-magnetite cannot be readily separated mechanically and vanadium content alone is too low to be exploitable.

d) Exploration of high quality bauxites in the Kaya-Kongoussi region. Bauxites suitable for production of refraction and abrasive materials (Al_2O_3 53%, Fe_2O_3 3%, TiO_2 3.5%) were located in 17 small deposits, totalling some 6 million tons. A group of 3 such deposits with 3 million tons of reserves has been estimated as an economic proposition for an annual production of 100,000 tons of calcinated bauxite. Estimated investment: US$ 3 million.

e) Exploration of gold occurrences at Gangaol (Dori).

Two zones of quartz veins (500 and 750 m long and 1.5 m wide) average 1.8 gr Au/t and 2.3 gr Ag/t is not an economic proposition at present.

f) Geochemical prospecting for base metals has located zinc-copper anomalies in the Gan-Kiembara region and nickel anomalies in the North of the Dori region.

Project UPV-16 (1970-1973): Mineral Exploration in the North
(Continuation of prospecting in the regions adjacent to the proposed railway.)
January 1971 - December 1973
UNDP Contribution: $1,169,900

a) Zone of weak copper mineralization, however, in promising geological environment, has been located in Mogtodo region.

Second phase of the current project: is planned in essentially the same region and with mainly the same objectives (general reconnaissance). It is hoped that by that time the results of the airborne geophysical survey carried out with the CIDA (Canadian) assistance will be available and will provide new targets.

ANNEX III

A comprehensive programme of mineral exploration for the Sahelian Region

A. History

1. The African Sahelian and desert regions are underlain by rocks with which, in other more accessible parts of Africa, numerous and varied mineralizations are associated. It is possible that important mineral deposits may be located in the Sahel if the necessary investments are made in mineral exploration for metallic and non-metallic ores.

2. Since antiquity, salt has been mined in Mali and in Chad. This mining has continued on an artisanal scale until now. Gold has been worked on what was called the Bambouk plateau in Mali, in Senegal as well as in Ivory Coast and Guinea for a very long time (possibly since the Pharaonic period). More recently iron has been worked by the inhabitants in Senegal, Mauritania and Mali. In Niger there are indications of very old copper exploitation in the region located West of Air.

3. Prior to 1960, the Sahelian region was geologically mapped and explored in a preliminary manner for diamonds, gold, tin, uranium, tungsten, niobium and tantalum. Beryl and lithium ores have been prospected in Mali and Senegal, and phosphates and iron ores have been investigated nearer the sea in Senegal and Mauritania. In Senegal, Mali, Upper Volta, Niger and Chad, gold has been mined in placer deposits, and in some instances in quartz veins. In the Air region of Niger, tin was mined during the Second World War and mining still continues on an artisanal scale. In the same region, uranium deposits were discovered and are in production now (1,000 tons

a year). In Senegal, important phosphate mines are exploited (1.5 million tons a year) and iron ore (up to 10 million tons a year) and copper (200 tons a year) are mined in Mauritania. In Upper Volta large manganese deposits (12 million tons) have been located but are not yet exploited.

4. After 1960, mineral surveys were conducted mainly by French (Bureau de Recherches géographiques et minières or BRGM), USSR, Canadian and Polish bilateral aid programmes and on a limited scale by private concerns. This exploration has located some mineral indications but as yet no mineral deposits. The UN completed the evaluation of the manganese deposits of Tambao in Upper Volta but on the whole the UN mineral survey projects conceived in the early 1960s were terminated without significant results (see details in Annex II). Indeed at that time, the use of geochemistry, airborne geophysics, photogeology and geochemistry had not yet been introduced to its present extent, and was not then as accurately understood as it is now. Also, many views on the relationship between tectonic fractures and mineralization have evolved. A full understanding of African volcano sedimentary formations is only now beginning to emerge, leading to the realization that these formations may be considered as "green stone" belts similar to those of Canada, Australia and South Africa, with possibilities of "massive sulphide" deposits, disseminated stratabound sulphide deposits and porphyry type copper and molybdenum deposits.

5. It is true that the work of BRGM as well as that of the UN projects have already located, in relation to these formations, numerous indications of copper, molybdenum, nickel, cobalt, lead and zinc. But these indications

need now full-scale revision and updating by experts familiar with such types of mineral deposits and able to interpret in the light of existing models, the messages given by geology, geophysics and geochemistry.

Mercury, antimony and baryte indications have been located on the Precambrian basement and they indicate possibilities of low temperature mineralizations related to fracturing of the Precambrian African Platforms. In the course of the UN and BRGM investigations certain possibilities may have remained unchecked.

Copper, lead and zinc mineralizations were located by BRGM and by UN projects on the contacts of the Precambrian basement with sedimentary formations in Mauritania, Mali, Upper Volta and Niger. However, these mineral indications were not fully investigated and the zones of contact between the basement and sedimentary formations not systematically explored. In the last few years, again, ideas and concepts on the location of strata-bound mineral deposits in sedimentary formation, on contacts with the basement, and on techniques of investigating them have evolved, and begun to be put into practice. The recent ideas on these types of deposits open new, wide fields for investigation.

6. Furthermore there are regions such as the Adrar des Iforas, AÏr and Tibesti which because of their difficult accessibility have never been completely explored for mineral possibilities.

7. Non-metallic mineral wealth has received little attention, especially in remote parts of the Sahel, yet there is an evident need for such commodities as clays for bricks, tiles, kaolins, and building stones; limestone for lime, possibly cement, and building purposes. Found along the coasts and railroads,

marbles and good quality granites, syenites and black basic and ultrabasic rocks suitable for polishing may be important; given the fact that for prime quality material, several hundred dollars per ton may be obtained on European markets.

8. It may be concluded from the above that perhaps only a minor part of the mineral potential has been investigated in the Sahelian region, and in any case that in the field of mineral exploration the Sahelian countries have important common problems, which it is recommended to solve in two general phases.

9. The first phase should include mineral investigation programmes according to latest concepts and techniques in the field of mineral exploration. The second phase should be designed for the execution of projects resulting from the results of the first phase.

B. Mineral objectives of the First-Phase Programme
(See country-by-country programmes under C.)

(a) The indications of mineralizations such as copper, molybdenum, nickel, cobalt, lead and zinc already discovered and related to the volcano sedimentary formations as well as to the facies of these formations should be studied and reviewed in the light of new concepts on green stone belt mineralizations. Programmes for further exploration of these mineralizations and formations should be formulated and budgetted. Such a review should be undertaken by highly specialized experts.

(b) The mineralizations of copper, lead and zinc related to contacts between basement and transgressive sedimentary formations in Mauritania, Senegal, Mali, Upper Volta, Niger and Chad should be reviewed. Programmes should be prepared for the investigation of zones of contact as well as for the study of stratabound mineralizations, metallic and non-metallic mineralizations that may be associated with sedimentary formations.

(c) The Sahelian region should be studied in terms of global tectonics to outline the possibilities of mineralizations related to fracturing and the reactivation of the old Precambrian Platforms. Similar studies of Russian, Siberian and Chinese platforms have proved to be very fruitful and have led to the discovery of numerous mineral deposits.

(d) Numerous gold placers and some quartz veins have been worked for coarse gold throughout the Sahelian region. They must now be reviewed for the possibilities of finely dispersed or colloidal gold. Geochemical exploration methods may be applied in further investigation and reassessment of the possible potential of these deposits.

(e) Numerous basic and ultrabasic intrusions or complexes exist in Sahelian countries. Until now, little attention has been paid to these rocks, but they may be associated with nickel, copper and other types of mineralizations. They should be carefully reviewed by specialists.

(f) Remote regions with acidic intrusions such as Adrar des Iforas in Mali, Air region in Niger and Tibesti in Chad, should be reinvestigated for their possibilities of tin, tungsten, niobium, tantalum and beryl as well as uranium. The recent volcanic formations of Tibesti should also be

examined for possible related mineralizations. Structural features should be studied, as should the possibilities of mineralizations of low temperature associated with volcanic activity.

(c) Non-metallics should include the study of the possibilities for building stones, and particularly for stones suitable for polishing, along the railroads and major roads; and the prospects for clays, kaolins, feldspars, limestones and building stones should be investigated.

Such reviews may only outline the programmes of the projects to be undertaken, though it cannot be excluded that they may lead to discoveries of workable mineral deposits only if they are sufficiently financed and staffed with competent personnel.

(b) A major part of existing geological data was collected long ago, frequently only for geological mapping and at a time when most present-day concepts on the significance of volcano sedimentary formations, on strata-bound mineral deposits, and on relations of mineralizations to different structural factors had not yet evolved.

Therefore a mere review and re-interpretation of the existing documentation can hardly lead to significant conclusions and recommendations. New field investigation and analyses should be performed with greater emphasis than in the past on regional features. For these reasons, even the first phase will be relatively expensive.

C. Work to be undertaken in each of the Sahelian countries

The overall programme outlined under B can be tentatively broken down geographically as follows:

1. MAURITANIA

(a) review of the volcano sedimentary formations with which copper and copper molybdenum mineralizations are associated;

(b) assessment of the mineral potential of the contacts of the basement and the sedimentary formations north and south of the "Dorsale de Regiat". Lead and zinc mineralizations have already been located along the contacts and their general significance should be assessed;

(c) the structural features of Mauritania should be studied with a view to suggesting possible mineral associations;

(d) ultrabasic rocks should be reviewed for their possibilities of copper, nickel, cobalt and platinum;

(d) Mauritania has a railroad and sea port so that dimension stones suitable for polishing should be examined as well as all other non-metallics suitable for export or local use.

2. MALI

The same type of studies as for Mauritania will be required, for volcano sedimentary formations, for the contacts of basement sedimentary formations, for basic and ultrabasic rocks, for general structures that may be associated with mineralisations as well as for non-metallics. Mali has had gold exploitations but the results have to be revised for their

possibilities of dispersed gold. Acidic rocks and associated mineralizations particularly those of Adrar des Iforas have already been studied by French and Russian geologists, but deserve being studied anew. They must be examined particularly as to whether there are no albitized cupolas with niobium, tantalum and beryllium mineralizations.

3. UPPER VOLTA

A project is already being executed in Upper Volta, but the review of its results by a team of highly qualified and specialized experts may prove to be of outstanding interest. Moreover, in the South-Western part of Upper Volta interesting indications of porphyry copper mineralizations in relation to volcano sedimentary formations have already been studied, although perhaps their implications have not been fully understood.

In the same region there are old gold workings that deserve close examination for dispersed gold. A study of structures in the South-Eastern part of Upper Volta has already led to the location of interesting copper indications. These studies should be extended to the whole of Upper Volta and especially to its South-Western part.

Along the Northern, Western and Southern borders of Upper Volta contacts run between the basement and transgressive sedimentary formations. Interesting mineralizations of copper and lead and indications of zinc have already been located along these contacts and the whole length should be carefully examined. The ultrabasic and basic rocks of the project area, as well as of other parts should be checked for their possibilities of copper, nickel, cobalt and platinum mineralizations.

The problem of non-metallics is the same as for Senegal and Mauritania. It must be underlined that Ivory Coast has already implemented an industry of polished granitic rocks and that in Togo marbles are in production and a cement plant is under study. Certain types of syenitic and granitic rocks in Upper Volta are suitable for polishing and may be transportable to the port of Abidjan.

4. SENEGAL

Senegal has the same problems as Mauritania, but does have old gold workings which should be examined for dispersed or colloidal gold.

The question of non-metallics should receive particular attention.

5. NIGER

Niger needs a completely fresh look at its mineral possibilities, particularly the Aïr region. All the above-mentioned reviews may be undertaken on Niger territory.

6. CHAD

The Aïr and Zinder areas have to be surveyed for mineralizations related to acid magmatism and should be carefully studied in terms of mineralizations that may be related to tectonic structures for which a study should be undertaken. The sedimentary formations surrounding these areas should be investigated for stratabound mineral deposits such as uranium, copper, lead, zinc, etc.

The Liptako region should be studied in the same way as has been outlined for Upper Volta and Mali, for its structural features as well as for mineral possibilities of the volcano sedimentary Birrimian formations.

D. Budget

A budget for this preliminary phase is outlined in the following table I.

Table I

BUDGET

	Man-Months	$ Total	$ 1975	$ 1976
1. EXPERTS:				
- Project Manager	24	60,000	30,000	30,000
- Specialist in green stone belt mineralizations (2)	48	120,000	60,000	60,000
- Specialist in stratabound deposits (2)	48	120,000	60,000	60,000
- Specialist in mineralizations (copper, nickel, cobalt, platinum, gold) related to the basic and ultrabasic rocks (1)	24	60,000	30,000	30,000
- Specialist in relationship of tectonic structures and mineralizations (1)	24	60,000	30,000	30,000
- Specialist in mineralizations related to acid magmatism (1)	24	60,000	30,000	30,000
- Specialist in dispersed gold mineralizations	24	60,000	30,000	30,000
- Specialist in non-metallics (2)	48	120,000	60,000	60,000
- Pilot (1)	24	60,000	30,000	30,000
Total experts -	288	720,000	360,000	360,000

	Man-Months	$ Total	$ 1975	$ 1976
2. SUPPORT PERSONNEL:				
- Accountant (1)	24	12,000	6,000	6,000
- Bilingual Secretary (1)	24	12,000	6,000	6,000
- Typists (2)	48	12,000	6,000	6,000
- Draftsman (1)	48	12,000	6,000	6,000
- Drivers (10)	120	24,000	12,000	12,000
- Miscellaneous personnel (10)	120	24,000	12,000	12,000
Total support personnel -	384	96,000	48,000	48,000

	US $
3. SUB-CONTRACTS:	
- Computerized collection of data	25,000
- Chemical analyses	25,000
- Mineralogical and petrographical analyses	10,000
Total sub-contracts -	60,000
4. EQUIPMENT:	
a) expendable	
- office furniture and equipment	30,000
- spare parts for vehicles	40,000
- camping equipment	10,000
- air conditioners	20,000
- miscellaneous	20,000
- fuel and oil	100,000
Total expendable equipment -	170,000

	US $
b) non-expendable	
- vehicles (12)	50,000
- aircraft (aircommander)	150,000
Total non-expendable equipment -	200,000
5. MAINTENANCE:	
- vehicles and aircraft	50,000
6. RENTING OF OFFICES	50,000
7. INTERNAL TRAVEL	50,000
8. MAIL AND CABLES	10,000
9. MISCELLANEOUS	15,000

SUMMARY

	Man-months	US $
Experts	288	720,000
Support personnel	96	96,000
Sub-contracts		60,000
Equipment:		
Expendable		170,000
Non-expendable		200,000
Maintenance - vehicles and aircraft		50,000
Renting of offices		50,000
Internal travel		50,000
Mail and cables		10,000
Miscellaneous		15,000
TOTAL COST IN DOLLARS		1,421,000

E. Follow-up

It is expected that at least ten national or regional projects would stem from this first phase study, and in turn need at least another $15,000,000 for a perioa of three years. Again for several of these projects subsequent phases may be needed, so that a conservative figure for the global investigation of the mineral potential of the Sahelian region at 25 million dollars could be spent over a five-year period or more, including all the work specified in Section V and Annex IV of this report.

ANNEX IV

Road stabilization materials
(by the Transport Section)

1. There is very limited need for expertise in geology and mining in connexion with common highway materials or their laboratory control. When a highway is being built, bank-run, base courses, and construction aggregates are usually obtained within or near the project's right of way. The highway is normally designed in function of available materials which are first identified and subsequently controlled through very standardized geotechnical procedures. The discipline of geology plays virtually no role in this process.

2. There is on the other hand a pressing need, not only in the Sahel but everywhere, to identify local materials which may be suitable to replace conventional highway materials such as asphalt or cement, and to determine their suitability range through laboratory tests. The recurring problem is invariably to modify or improve the characteristics of locally available soil materials through the mechanical, chemical, or electro-static action of additives. The characteristics to be altered include shear cohesion, permeability, plasticity, swell, and others associated with the material's origin, weathering and state.

3. The problem as we see it, is to identify potential additives in the course of broad geological exploration, then to ascertain the purposes for which the additives can be used and the methods to be followed for such use.

4. Several potential additives come to mind in connexion with the Sahel. They include natron, decomposed granites and scoriae, pozolanic soils, gypsum, and lime. We stress it however, that the terms of reference for any geologic explorations should provide for asking two questions in connexion with highways. First what materials are available? Second, what can these materials be used for, and how?

5. Identification and quantification of materials should be a first order of priority. Requirements in this connexion would include participation in the exploration team of a geologist specialized in geotechnics and allied chemistry. Modest, portable field testing facilities would be required.

6. The second order of priority would include assessment of materials and of their use through laboratory testing. The laboratory would not necessarily need to be established in the project area since samples could be shipped for testing over comparatively large distances.